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DETERMINATION OF THE WATER VALUE OF A SNOW COVER WITH RADIOACTIVE SUBSTANCES

Wasserwirtschaft (Water Economy), Vol 8, No 4, Vienna, April 1956, pages 86-93

Viktor Fischmeister, of Linz

1. Definition of the Water Value

The winter snow cover stores up the precipitation during the cold season and yields up this supply again in the spring. For many purposes, and not least for the water economy, it is important to learn about this process in its spatial distribution and its chronological course. The amount of snow $G(t)$ stored by a definite area $F(m^2)$, e.g. drainage area of a river, equals

$$G = \int_F g \cdot dF \, , \tag{1}$$

where g is the snow load per unit surface (horizontal projection), or, in the language of nuclear physics, the coefficient of mass (t/m^2) and dF the horizontal projection of the surface element (m^2). Then again

$$g = \int_{h_S} \gamma_S \cdot dh_S \, , \tag{2}$$

with γ_S equal to the specific weight of the snow cover (t/m^3) and h_S equal to the depth of the snow measured vertically (m). If we think of F as covered not with snow but with water, in such a way that each surface element is covered with an ideal water load equal to the actual snow load, then

$$\gamma_W \cdot h_W = \int_{h_S} \gamma_S \cdot dh_S \, , \tag{3}$$

where γ_W represents the specific weight of the water (t/m^3) and h_W the ideal height of water measured vertically (m).

h_w is called the water value of the snow cover.

Since the snow density γ_s is subject to local and chronological variations -- e.g. 0.1 t/m^3 for freshly fallen snow or 0.5 t/m^3 for moist névé -- knowledge of the depth of snow h_s alone is not sufficient to determine the storage; we must go back to the snow load per surface unit g or to the water value h_w. Since it is impossible in practice to determine the water value for every single point in the countryside, we content ourselves with determining it for a few selected characteristic places and multiplying these values by the corresponding surface areas, which must be carefully delimited.

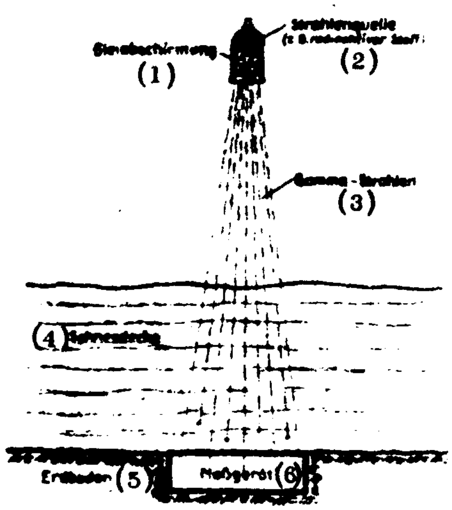
2. Determination of the Water Value with the Snow Gauge

The traditional instrument for determining the water value is the snow gauge, a cylindrical metal tube with a hard, toothed cutting edge, which is driven by turning and pressing through the snow to the ground. When the tube is pulled out with the proper care the core of snow cut or punched out remains inside it, so that it is possible to determine the weight of this core of snow.

If D represents the internal diameter of the snow tube (m) and G the weight of the snow core (t), the well-known equation

$$G = \frac{D^2 \cdot \pi}{4} \cdot \gamma_w \cdot h_w \qquad (4)$$

offers the possibility of computing the water value h_w.



Legend:

(1) lead shielding
(2) radiation source (e.g. radioactive substance)
(3) gamma rays
(4) snow cover
(5) earth
(6) measuring instrument

Figure 1. Diagram of the radiation probe.

3. How the Radiation Probe Works

The radiation probe, on the other hand, is based on the absorption of gamma rays (photons) in the snow cover. The arrangement and mode of operation of such a radiation probe are illustrated by Figure 1. The radiation source may be a radioactive substance, say radium, or the radioactive isotope of cobalt with the atomic weight 60 (Co^{60}) produced in the atomic pile. This is fixed rigidly above the snow cover to a bracket attached to a pole driven into the ground, far enough above the ground that it is not covered by the snow at its extreme depth. A lead shield prevents radiation upward and to the side, so that organisms nearby are not endangered. The radiation downward toward the snow cover is partially absorbed by the snow; the rest penetrates the snow cover and is recorded by the measuring instrument located under it.

Where T_0 represents the number of photons that would strike the measuring instrument per unit time if no snow were present, T the number when the protons penetrate vertically through a snow cover with the water value h_w, e the base of the natural logarithms (2.718), and k a constant,

$$T = T_0 \cdot e^{-k \cdot h_w} \tag{5}$$

for any pure snow cover, independent of density, crystal structure, temperature, and distribution, as well as for water and ice, or in other words for H_2O molecules in any conceivable arrangement and at any temperature. The absorption of gamma rays by air molecules is so small in comparison to the absorption in water that it may be ignored and need not be further taken into account in this connection.

The number of impacts per unit time T and consequently the T-proportional number of impulses per unit time registered is thus a direct measure of the water value h_w. We thus have here, in contrast to the traditional snow gauge, an **interference-free measurement** method. Since the gamma rays are changed in the measuring instrument into adequate impulses of electrical energy, a fully automatic measurement with telemetering of the results is easily possible. For measurements in terrain difficult of access, as e.g. in the mountains, this characteristic will be particularly appreciated.

At the Upper Austrian Power Company, Inc., relevant experiments were done as early as the winter of 1953-54, with radium in a dosage of five millicuries as the radiation source and a Geiger-Müller counting tube as the counter. In accordance with a desire expressed by ministerial councillor Otto Lanser of the Federal Ministry of Agriculture and Forestry, the next winter an experimental apparatus was tested that was made by Siemens & Halske G.m.b.H. and adapted to the special environmental conditions.

4. Design of the Experimental Apparatus

In this apparatus Co^{60} in a dosage of 40 millicuries is used as the radiation source and a Geiger-Müller counter as the measuring instrument. The impulses registered by the counter are electrically amplified and are transmitted at long range by a battery-powered, amplitude-modulated ultra-shortwave sender, 59 megacycles, 3 watts. A switch clock switches the sender on once a day and switches it off again after ten minutes. Counter, sender, and switch clock are all enclosed in a waterproof metal container, since they lie for months at a time under the winter snow cover.

The receiver is built to be plugged into the power lines -- alternating current, 220 volts, 50 cycles. It takes the electromagnetic waves emitted by the sender, amplifies them, and in the "integrator" electrically forms the quotient of the number of impacts registered by the time, so that the the impulse frequency can be read directly at the measuring instrument.

The device has two ranges of measurement, one between 0 and 10^4, the other between 0 and $3 \cdot 10^4$ registered impulses per minute. In this connection it should also be noted that the Geiger-Müller counter registers only a few percent of the hits as impulses. Under a heavy load -- more than 15,000 recorded impulses per minute -- the resolution decreases rapidly.

5. Calibration of the Experimental Apparatus

The device was delivered late in December 1954, put in operation for testing in our laboratory at Gmunden at the beginning of the new year, and empirically tested, after elimination of damage occasioned by transport, on 22 February 1955.

For this it would have been simplest to put the counter in the bottom of an open vessel, to hang the source of radiation vertically above it at the desired distance, to let the vessel gradually fill with water, and to determine the deviation of the pointer as a function of the height of the water above the counter. This simple procedure unfortunately had to be given up, because from our experiments in the spring we knew that in absorption experiments on circumscribed objects scatter phenomena in the layer of material change the characteristic curve as compared with that of an unlimited object such as an extensive snow cover. To eliminate this error we calibrated the radiation probe on the Traunsee.

First the radiation source and the transmitter were fastened at a fixed distance from each other on a wooden scaffold. After the empty value had been determined (water level 0), the apparatus was immersed by degrees in

the lake, the radiation source being down, and so in the water, and the metal container with the counter up, and so in the air, in contrast to their relative positions in later use. This was done because the manufacturer feared penetration of water into the apparatus, although the shielding of the source of radiation, the lead bell already mentioned, again created a "circumscribed object" and thus distorted the characteristic curve of the device to an unknown degree. This defect in the experimental arrangement of course has the most unfavorable effect at low water levels, when practically nothing but the lead bell is filled with water.

Since there were some waves in the water during the measuring in spite of careful selection of place and time, it was hard to find the height of the water above the source of radiation with the desired accuracy.

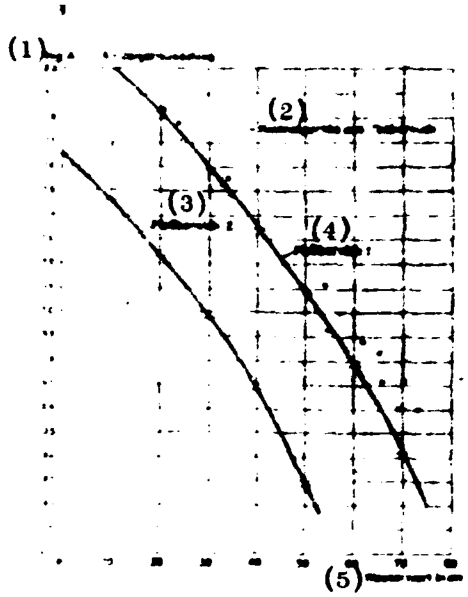
The distance between radiation source and counter was set in accordance with the manufacturer's instructions at 2.37 m; at water value 0 for the measurement range of low sensitivity a needle deviation of 90 was found with 100 scale units maximum, representing a very good exploitation of the instrument's range. But in testing on the ground the distance between radiation source and counter was set at 3.38 m as a precaution, since at the time it was set up there was already a snow level of more than 2 m and there was thus danger that the cobalt preparation might be snowed in, so that wrong measurements would result.

Since the impulse count per unit of time varies inversely with the square of the distance, the change in distance could be taken into account by a simple correction factor for the characteristic curve, but that did not take into consideration any change that might take place in the yield of the device — that is the ratio between actual impacts and recorded impulses.

In this first calibration, moreover, sender and receiver were set up at a distance of only about 50 m, and the modulated antennas indispensable for receiving at a distance were used, so that the electromagnetic waves picked up by the receiver were several times as strong as in normal operation. This overexcitation caused internal vibrations in the receiver which we did not notice until later experiments, but which distorted the characteristic curve to an unknown degree.

Lastly, in this calibration certain slight errors presumably also crept in due to high-frequency interference, which simulated a higher impulse frequency. Light motorcycles were particularly annoying in this respect. With the intensification of motor traffic toward spring these disturbances became intolerable in the receiving station located on the Salzkammergut federal highway and rendered accurate reading of the instrument extraordinarily difficult. Such errors due to high-frequency interference show up particularly strongly with small deflections of the needle, i.e. with high water values.

With small deflections of the needle, too, even the statistical fluctuation in emission, i.e. in impulse count per unit time, also shows up in a slight unsteadiness of the needle which adds to the difficulty of reading.



Legend:

(1) log A   A - deflection of the needle
(2) o check points from field tests
(3) measurement range 2
(4) measurement range 1
(5) water value in cm

Figure 2. Characteristic curves of the radiation probe.

All radioactive substances "age," i.e. the intensity of their radiation decreases with time. Where Z_0 represents the number of disintegrations of atoms per unit time at the beginning of the tests, Z the same t years later, α a constant (1/years), and e the base of the natural logarithms, the disintegration process follows the equation

$$Z = Z_0 \cdot e^{-\alpha \cdot t} . \qquad (6)$$

For Co^{60}, $\alpha = 0.131$, corresponding to dying out of the radiation intensity to half the initial value within 5.3 years (half-life). In very exact measurements either radioactive substances with very long half-life must be used, such as natural radium, or else the "aging" must be properly taken into account. In our case it was possible to calculate with a constant reduction factor for the entire duration of the experiment.

After the field testing of the apparatus, which will be described in a later section, and a necessary maintenance job, the probe was calibrated once more on 22 February. This time the distance between radiation source and counter was raised from 2.37 m to 3.38 m, the distance that had been used in the field. We also found a new place for the test, away from heavily traveled roads, so as to be as free as possible from high-tension interference. As a precautionary measure, too, the distance between sender and receiver was raised to 200 m and the modulated antenna of the sender was replaced by a simple piece of wire, so as to eliminate the afore-mentioned internal vibrations in the receiver due to overexcitation. Lastly, we took the decrease in radiation due to "aging" into account in accordance with Equation 6. From this second calibration we obtained the characteristic curve of the device as shown in Figure 2 and used from then on in evaluating the experimental results. This curve shows

the logarithm of the number A read off the scale of the measuring instrument (maximum deflection 100 corresponding to log $A = 2$) and the corresponding water value in cm for measurement ranges 1 and 2. As will be seen, the low-sensitivity measurement range (2) is used with the increased distance between radiation source and counter only at a water value below 10 cm, and so is hardly ever used, while at a water level above 53 cm the deflection of the needle drops below 10 graduations (corresponding to log $A = 1$), or less than one tenth of the maximum deflection, so that the accuracy of reading is not satisfactory.

If we assume that the recorded number of impulses per unit time or the scale reading A is proportional to the frequency of impact T, then according to Equation 4 the following relationship must obtain between scale reading A at water value h_W and scale reading A_0 at water value 0:

$$\log A = \log A_0 - k \cdot h_W \ , \qquad (7)$$

i.e. the characteristic lines must be straight lines. In fact, however, as Figure 2 shows, both are curved lines. In the lower range of deflection this is ascribable to a zero error of the instrument, and in the higher range to a decrease in power of resolution due to the higher number of impulses per unit time; i.e. the recorded number of impulses per unit time becomes smaller and smaller in proportion to the impact frequency beyond a certain upper limit. This is a phenomenon characteristic of counter tubes.

Correlation of this characteristic line obtained from the second calibration with that obtained from the first calibration was found not to be possible. In the second calibration the water values corresponding to a given needle deflection were lower throughout, by 2 to 11 cm. This lack of agreement was not surprising in view of the additional sources of error, already discussed in detail, which existed in the first calibration. Of course the possibility cannot be rejected with certainty that perhaps the characteristic curve of the instrument had changed during test operation.

The counter represents a particular risk in this respect, even though modern tubes are not so sensitive to temperature or so subject to aging phenomena as the older designs.

Certain small interferences also occur, though they are negligible at the impulse frequency used, by reason of cosmic radiation, the intensity of which fluctuates slightly at one and the same place and increases with altitude.

In precision experiments the last-mentioned two sources of error — change in the characteristic of the instrument and change in cosmic radiation — are eliminated by testing the two quantities before and after the actual measurement and accepting a measurement only when the limiting test measurements show agreement.

The characteristic curve shown in Figure 2 is precisely valid only for pure snow, of course; in very dirty snow, such is sometimes to be found in the spring toward the end of the thaw, absorption in the dirt layer sometimes shows up as a disturbing factor.

6. The Testing of the Experimental Instrument

Our plan for testing the experimental instrument was to set up the radiation sound and transmitter at a suitable place in the mountains and the receiver in Gmunden, the location of the headquarters of the Oberösterreichische Kraftwerke A.G. (Upper Austrian Power Company, Inc.). Once a day a signal was to be transmitted from the radiation probe, and once a week a snow core was to be taken in the vicinity of the radiation sound; then the weight of that snow core was to be determined and the water value computed according to Equation 4 and compared with the reading of the radiation sound.

The radiation sound was set up on the north slope of the Eibenberg, on a small bare spot in the middle of the woods, near a cowherd's hut, at 1460 m above sealevel. The receiver was placed in the lakeshore bathing area at Gmunden at 424 m above sealevel, attached to the existing meteorological observation station, kindly tended by Mr. Egelkraut, the manager of the lakeshore. The distance between sender and receiver was 14.6 km. A line of sight existed between the two along the length of the Traunsee.

We set up the sound and transmitter at a point where favorable conditions for testing the instrument were to be expected. We were especially interested in a heavy and long-lasting deposit of snow, to exhaust the range of measurement of the instrument and to obtain, in spite of the advanced season, as extensive observational material as possible. The place should be shielded from wind and sun, so that the depth and density of the snow would vary near the radiation sound only within narrow limits and the weekly control measurements with the conventional snow gauge would give valid results.

The sound should be at a suitable distance from the receiving station and with an unbroken line of sight to it, to ensure satisfactory reception in all weathers; the location of the receiving station was determined by organizational considerations.

The location of sound and sender also had to be accessible even in bad weather, so that the planned weekly control measurements and immediate repairs in case of breakdown would be possible. It had to be as secure as it was humanly possible to make it from natural cataclysms, especially avalanches and lightning, and must lie apart from known ski routes so as to avoid as far as possible interference by outsiders.

Lastly, it was desirable to have near by some shelter, however modest, for the men who set up and tended the instrument, as well as to accomodate the battery and auxiliary equipment, such as snow gauge, scales, auxiliary receiver, and tools.

Meteorological considerations, such as a wish to obtain typical statistical figures for a particular area, played no part in the choice of location.

Setting up the device at the beginning of March 1955 turned out to be a laborious undertaking. About 80 kg of equipment, namely the heavy, bulky antenna mast, the lead container with the radioactive preparation, the sender with the counter, the battery, cable, and auxiliary equipment, tools, and provisions, had to be carried in severe cold and deep snow to the site; this involved overcoming a difference in altitude of 1000 m on a poor path through steep woods. Setting up the mast, attaching the guywires, and installing the sender required digging through 2 meters of snow, which in low places was hard packed and frozen. Camping in the primitive, untended hut in the winter cold was a great hardship. Keeping in touch with the personnel of the station in the valley was very complicated and tedious.

Despite all precautions the snow was disturbed in its uniform stratification in the course of the digging, so that the local variations in density of snow that existed from natural causes were increased. This produced certain difficulties in evaluating the instrument that will be discussed in detail later. If such testing is done in the future it will be useful to establish the mountain station in good time, that is in the fall before any snow is lying on the ground, and to level the ground in the immediate vicinity of the place intended for the sound, so as to promote the formation of a uniform layer of snow.

The switch clock of the transmitter was set so that every day from 1255 to 1305 hours, i.e. for ten minutes, a signal was transmitted to the station in the valley. The receiver itself was switched on by hand each time about five minutes before the expected beginning of transmission, so that the instrument was already ready to receive when the first impulses came in from the transmitter. Then it was possible to observe the gradual deflection of the needle, its stopping at the transmitted value, with very small fluctuations when reception was uninterfered with, the temporary increases in deflection occasioned by passing motor vehicles, and finally the slow return of the needle to its position at rest after the sender is switched off.

The instrument was put into operation 8 March 1955. From that day on it transmitted its signal to the valley station at the time set on the switch clock, and that signal was always well received. No influ[illegible] the weather on the quality of transmission could [illegible]ved.

Once a week two men, and in bad weather by way of precaution three men, climbed up to the snow sound, checked out the installation, took samples with the conventional snow gauge in the vicinity of the radiation sound -- within a radius of about 6 m --, determined the weight of this sample, and measured with an avalanche probe -- a slender round steel rod for searching for people buried under an avalanche -- as well as the snow gauge at each place where snow borings were taken.

Since the ground was not frozen under the snow, it was possible each time to drive the snow gauge through the snow

and some way into the loam beneath it, so that a little plug of mud closed the sampling tube and prevented any part of the snow core from being lost when the tube was drawn out. The inside diameter of the snow gauge was 10 cm.

Where G denotes the weight of the snow core in kg, t_D the depth of snow at the radiation sound in cm, t that at the mechanical probe in cm, by substituting the corresponding values in Equation 4 we may compute the water value at the radiation sound as follows:

$$h_D = \frac{40}{\pi} \cdot \frac{t_D}{t} \cdot G(\mathrm{cm}) \;. \tag{8}$$

The factor $\frac{t_D}{t}$ takes account of the difference in depth of snow at the radiation sound and at the mechanical sound.

When it was found in the course of the investigation that the snow density also exhibits not inconsiderable local variations, at each control measurement two or even more snow cores were taken in locations symmetrical with relation to the radiation sound and the arithmetical average of the water values computed in accordance with Equation 8 used as a basis of comparison with the radiation sound. Whether these local variations in snow density are to be ascribed to disturbance in setting up the apparatus or whether they are connected with local conditions cannot be decided on the basis of our tests and observations. I believe, however, that the location was not very happily chosen in this respect. In all other respects -- heavy and long-lasting snow cover, favorable conditions for reception, sure access, no disturbances by natural cataclysms -- the location turned out to be very favorable, and throughout the winter no stranger stopped in the vicinity, for we never saw the marks in the snow that in that case would have been unavoidable.

Installation, checking, and removal of the experimental instrument made great demands on the reliability, the technical knowledge, the workmanlike dexterity, the mountaineering ability, and the toughness and endurance of the installation and servicing crew. Only by their splendid achievements was it possible to carry out the experiment at all in spite of the advanced season and thus get useful data so early. And so let us here express heartfelt gratitude to Mr. Max Kölblinger and his men for their exemplary work.

The results of this test are shown in Figure 3, which contains the progress curve of the water value according to data furnished by the radiation sound, comparison curve according to the samples taken with the conventional snow gauge, and also the progress curve of snow density as computed from the depth of the snow and the weight of the snow core, as well

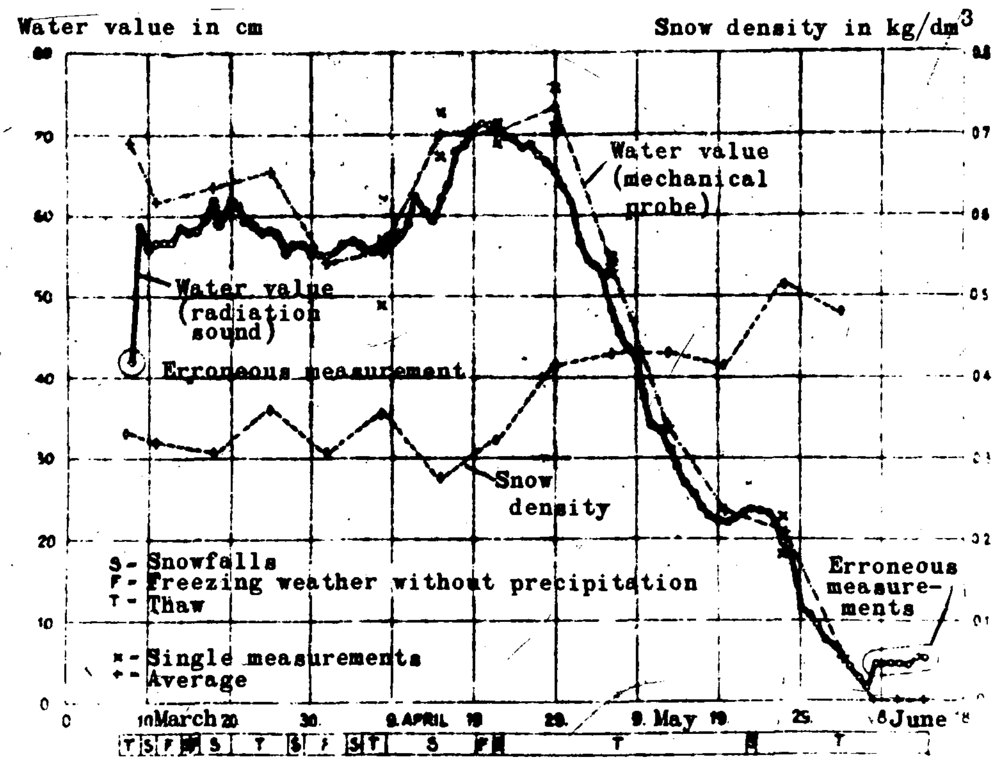


Figure 3. Progress curves of water value and snow density.

as general information about the weather, which is quite reliable, inasmuch as it is based on the measurements of the observation station situated nearby on the Feuerkogel at about the same elevation.

For coordination of the variations in the water value with the weather condition we contented ourselves with three characteristic features of the weather. First of all we have indicated days with snowfalls, because on such days the water value of the snow cover rises; then days with freezing temperature and no precipitation, on which the water value remains practically unchanged, and thawing weather, which causes a decrease in the snow cover.

The progress curve of water value according to the radiation sound begins with an erroneous measurement, which may be connected with the fact that at the time of the signal the shaft through which the sender was lowered beneath the snow cover was still partially open. Although the sender was pushed from the deepest point in that shaft through a small lateral passage to a point beneath the radiation source, so that the profile of the snow cover through which the radiation passed remained practically undisturbed, still a not inconsiderable portion of the scatter radiation appears to have found its way to

the counting tube via the still partially open shaft, so that a lesser depth of snow was simulated than was actually present.

The data for the last seven days must also be thrown out, since at that time surely the last snow had already melted, but the radiation sound still showed a depth of 5 cm of snow. In fact it was found at the time of the calibration already discussed, just after the actual testing, that one condenser had gone bad. This defect may have developed some days before the end of the testing, or around 9 June 1955.

Otherwise the course of the progress line of water value according to the radiation sound shows a very smooth succession of daily values, which speaks well both for the quality of the instrument and also for the careful work of the observer. The recorded changes in the water value are also excellently coordinated qualitatively with the state of the weather, as a comparison of the relevant data in the graph shows.

During the inconstant weather between 8 March and 8 April the variations in the water value were slight; the abundant snowfalls between 9 and 19 April brought about a considerable rise; and the concluding thaw caused a steady drop until on 8 June the last snow had melted away from above the counter. Around 24 May the "icemen," about a week late, brought cold air and snowfalls, accompanied by a slight rise in the water value of the snow cover. Two small irregularities in the progress line of the water value, namely a slight drop 19 March which was regained on 20 March and a greater drop 13-14 April which was regained on 15 April, cannot be correlated with the state of the weather. They may be explained by blowing snow or by a false indication because of high-frequency interference.

The average density of the snow remained practically constant at 0.32 kg/dm^3 until the onset of the thaws and then from then on gradually rose to 0.5 kg/dm^3. This rise is to be attributed to the gradual wetting of the snow and to simultaneous settling during the thawing process.

The progress line of water value according to the measurements with the conventional snow gauge shows the connection with the state of the weather less clearly than that according to the radiation sound. This inadequate correlation is due to the fact that we could only take samples with the snow gauge once a week and that at first, when we did not yet know of the significant differences in snow density between two very closely situated profiles, we contented ourselves with only one snow core on each occasion, while beginning with the fifth control measurement two or more cores were taken each time.

The report of 25 March based on only one snow core, e.g., and that of 29 April based on two snow cores cannot be correlated with the weather conditions of the preceding week and must be regarded as incorrect measurements.

The measurement data taken with the mechanical probe are higher in the majority of cases than those taken with the radiation sound, but the differences become less as the season advances and the water value decreases. It is also clearly evident that the agreement grows with the number of snow cores on which the individual control point is based. We attribute this discrepancy to the following causes:

a) The local differences in the snow cover already mentioned several times, and especially a loosening up of the snow cover at the point irridiated in the course of installing the equipment,

b) The insufficient accuracy of reading of the instrument at high water values, also already mentioned, because of smaller needle deflections and unsteadiness of the needle,

c) A change — although not detectable — in the characteristic of the instrument during testing, and

d) The sensitivity to high-frequency interference, which has already been discussed at length in connection with the discussion of the calibration results.

The increase in the difference between the results obtained with the radiation sound and the mechanical probe with increasing water value is very clearly evident from Figure 2, where beside the calibration curve the water values corresponding to the individual needle deflections but computed according to the mechanical probe are also plotted in.

A summary of the sizes of errors is given in Table 1, where h denotes the water value according to the radiation sound and h_D the water value at the same place as determined with the mechanical probe.

Table 1. Size of Errors

$\frac{h - h_D}{h_D}$ % From	To	Number of Control Measurements
+ 5	0	2
0	-5	4
- 5	-10	3
-10	-15	4

A meteorologically important result of the experiments is the finding of the great depth of snow and high water value of the snow cover in March and April, which may be connected with the particular location of the

observation point — north slope, about 100 m below the main ridgetop, surrounded on all sides by forest — and also with the peculiar character of the weather during this particular winter. Another interesting feature is the late occurrence of the maximum — 20 and 21 April — with a water value of 71.1 cm, and also the long continued presence of the snow cover, namely until 4 June.

The importance of the snow cover of the winter mountain country to the water economy becomes clear when we consider that in our case on 21 and 22 April, i.e. at the time of the maximum value, about a third of the annual precipitation (normal year) was stored up in the snow cover.

7. Criticism of the Testing Method and of the Measuring Procedure and Apparatus

The testing method was imperfect in many different respects, but let us begin by stating in our defense that the defects about to be discussed only showed up in the course of the testing, and that insofar as that was possible they were immediately remedied.

It must be considered an obstacle to evaluation that, as we have already mentioned and accounted for, we did not succeed in getting the calibration curve taken before the testing to coincide with the one taken after the testing. In this article we have worked with the calibration curve taken after the testing, as it is more soundly based, although a displacement of the characteristic curve of the instrument or of the counting tube during the testing is still conceivable. This conjecture is further strengthened by the fact that the characteristic curve developed after the first calibration fits still better into the sequence of control points (mechanical probe) than the characteristic curve actually used.

We have already pointed out in some detail the influence of high-frequency interference and the surprisingly great local differences in snow density from profile to profile.

A small change in the distance between radiation source and counting tube which took place at an unknown time between the setting up and the taking down of the experimental apparatus did not have to be taken into consideration in the evaluation, since its effect was negligible. But in setting up such devices this circumstance should be borne in mind, since the radiation density varies with the square of the distance.

In summary it may be said that while in the course of the testing various shortcomings either of the method of testing or of the arrangement of the apparatus did show up, still the results are reliable enough for us to reach on that basis a critical opinion of the method of measurement and of the instrument. No defects in the method of measurement could be could be established, but the apparatus, and especially the

Figure 4. Primrose (Primula auricula).

electrical telemetering of the results, still exhibits shortcomings in may respects.

First of all the device's liability to damage in transport must be remedied, and then, too, its weight is excessive. It should be possible to design such a device much more robust and much lighter.

The very inconvenient sensitivity to high-frequency interference could, in the opinion of professional radio men, be eliminated by raising the frequency and using frequency modulation instead of amplitude modulation.

The internal frequencies that interfere with calibration could be avoided by improved circuitry. Some importance attaches to this circumstance because such devices, because of the variable counting tube characteristic, must be recalibrated fairly often. For purposes of installation and control a voice radio communication system between the sending and receiving stations would be very desirable. It should not be difficult to design such equipment as part of the device. For our purposes the distance of 2.37 m between instrument and counter provided by the designer would just been sufficient; the greatest depth of snow reported was 2.20 m. But on the high plateau of the Totes Gebirg near the Albert Appel house at 1660 m above sealevel last winter snow depths of more than 3 meters were read on the snow gauge, and that by no means represents a limiting value. It thus becomes necessary to raise the sensitivity of the instrument, but without resorting to a higher radiation dosage.

The varying demands of science and industry in the way of measurement range, accuracy, power supply, and mode of transmission are best met by a system of semi-independent components. The measuring procedure chosen makes it possible for one and the same receiver to receive and/or record signals emanating from several transmitters and also to carry other meteorological elements, such for example as air temperature and air pressure, on the same telemetry channel.

We thus arrive at a highly colored picture of the most varied possibilities, with the long-range goal of unmanned weather stations in uninhabited areas, which operate automatically and transmit their data to a central location, where these data are also automatically recorded. We might go a step further and instead of the usual recording paper provide punched cards which could be put directly into computing machines for statistical evaluation from the most varied standpoints.

But rather than close my discussion with consideration of certain developmental tendencies, I should like to add a few words about the handling of radioactive substances; for these substances are more and more frequently finding their way out of the nuclear physics laboratories into the world of the engineer, -- more and more people are having to do with such substances and must be made familiar with their physiological effects.

And these effects are very remarkable. In small doses animating and stimulating, in excess debilitating and depressing, in extreme doses they lead to severe psychic injuries, sickness, and death. And man has no sense organ that makes known to him the presence of such rays or that warns him against an excess, and the effects show up late -- in many cases too late.

Work with small quantities as a matter of principle, then; check the working conditions of the people under your direction with the radiation warning device, and take counsel in time with experienced experts, nuclear physicists, hygienists, and doctors. But do not be overanxious, for every man is constantly subjected to an uninterrupted shower of a much harder radiation, namely cosmic radiation, without knowing anything about it or being injured by it.

Nuclear physics is opening up to us a new, mysterious, and inconceivably powerful side of nature. Good and evil, fortune and misfortune, life and death lie very close together here, just as on the ridge of the Eibenberg at the time of my last inspection trip at the end of May the woods on the shaded side were still in their winter dress, stiff and dead, while a few paces further into the rocky banks of the steep south flank the splendid clusters of leaves and fragrant blossoms of the primrose (primula auricula) by the thousands brought news of new life.

Summary

The concept of the water value is defined and the determination of the water value with the conventional snow gauge explained. On the basis of a schematic diagram the mode of operation of the radiation sound and the arrangement of an experimental apparatus are described. Then the calibration and testing of the experimental apparatus is recounted and a criticism is offered of the testing procedure, of the method of measurement, and of the experimental apparatus. The article closes with a general reference to the handling of radioactive materials and the precautionary measures necessary in working with them.